**CLAIMS**

**1. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, with various user equipments **(2)** and a head-end equipment **(1)** in two-way communication over the electricity network, and where transmission optimisation occurs in the both the upstream channel defined as the channel running from the user equipments to the head-end equipment, as well as the downstream channel, defined as the channel running from the head-end to the user equipment; and where furthermore, sharing of the electricity network in both the upstream and downstream channels occurs by means of frequency division duplexing (FDD) and/or time division duplexing (TDD); and where a signal with OFDM modulation (orthogonal frequency division multiplexing) is transmitted with multiple carriers, with different modulation and with forward error correction/detection codes sent over the whole channel using very narrow bandwidths, and characterized in that it comprises:

- continual monitoring of communication quality by estimating signal to noise (S/N) ratio in the various carriers in the upstream and downstream channels, this estimation being undertaken by receptors in the head-end and user equipments respectively;
- monitoring the state of the network at each moment by the user equipments independent of whether or not the information is destined for the user;
- selection of the optimum transmission mode starting from the monitoring of communication quality, packet by packet, of the number of bits per carrier, the redundancy introduced by means of the FEC, the FEC and /or the transmission mode, and all of this so as to be

able to carry out optimum sharing of the network at all moments, in both time and frequency and so that transmission capacity over the electricity distribution network for the multiple user equipments is maximized.

**2. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 1, characterized in that estimation of the signal to noise (S/N) ratio is carried out beginning from the error signal in the receptor demodulator, this being determined by the difference between the signal that enters the receptor demodulator and the desired signal, that is, the signal estimated to have been transmitted if the point of the constellation in each carrier had been situated in optimum position according to the possible points of the constellation used in this carrier; where S/N estimation, from the demodulation, is adequate if the bit error rate (BER) is sufficiently low so as not to affect the process of estimating the noise level.

**3. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 2, characterized in that monitoring of communication quality in the upstream and downstream channels comprises the estimation of noise power (N) by means of the demodulator of both the user and head-end equipment only in the carriers of the received signal where the modulation used is known and, the value for noise power is obtained from an estimation of the mean squared value for noise beginning from the error signal in the demodulator and weighting the noise squared over a certain number of symbols so as to avoid that impulse noises or noises of short duration in the electricity network produce errors in the estimation of the noise power in reception.

**4. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 2, characterized in that when monitoring communication quality in the upstream and downstream channels, the user equipments and the head-end estimate the power of the signal (S) selectively, using a normal level in reception that compensates for the effects of the channel, to represent signal power, where this level is previously established and known by design, or by measuring the power of the received signal, preferably having carried out the equalization process so as to compensate for the effects of the channel on the transmission signal.

**5. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 4, characterized in that the error signal of the demodulator is accumulated following demodulation of the received signal in the carriers where the modulation used is known, preferably having firstly filtered the estimate of noise power in the various carriers so as to avoid oscillation in said estimation.

**6. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 5, characterized in that calculation of the S/N is carried out after having accumulated samples of demodulation error selectively during windows, that is, time periods, that last for M symbols or during windows where at least P measures have been carried out in all the carriers, where M and P are previously established values known by all the equipments.

**7. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 5, characterized in that in

transmission via the downstream channel certain carriers are sent that have a pre-established, fixed modulation, known to all equipment, that preferably has low S/N requirements and whose position varies in time, namely, grid, so that the user equipment, knowing the modulation used to transmit the grid carriers, monitors communication quality including when the information sent by the head-end is directed to another user equipment, and furthermore, the process comprises the accumulation of noise samples, even when the user is not the destination for the transmission.

**8. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 2, characterized in that when monitoring the upstream channel, the head-end only carries out estimations of the S/N for a certain user equipment while this is transmitting data in the upstream, so that when the head-end wants to update its estimate of S/N for a user equipment it selectively carries out one of the following actions:

- orders the user equipment to send specific information so that the head-end may measure the S/N and therefore monitoring is not blind because the receptor knows the information sent by the transmitter;
- orders the user equipment to transmit the information that is wants to send and in this case, monitoring is blind because the receptor does not know the information sent although it does know the modulation used for its transmission.

**9. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 8, characterized in that monitoring of the communication in the downstream channel

is carried out by means of estimating the S/N ratio in the various carriers received by the head-end equipment.

**10. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 1, characterized in that the election of optimum transmission mode is selected starting from the monitoring of communication quality and according to the rules:

- If S/N is sufficiently high modulations with greater density, namely, with a larger number of bits per carrier, will be used, the number of points in the constellation being selected by means of comparing the S/N estimate with a series of previously defined S/N thresholds, along with variable FEC codes to increase the transmission of information to the maximum, all the while maintaining a determined bit error rate (BER);
- If S/N is very low, or if there is a need to send information to one or more users in a more secure form, then the same information is sent various times in various frequencies and /or times, that is, transmission with diversity in HURTO mode, namely, high ultra reliable transmission OFDM.

**11. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 10, characterized in that starting from S/N in the various carriers, from the packet loss rate (PLR), from the quality of service (QoS) required, and from the size of the information to be sent with respect to the capacity of the OFDM symbols, the FEC code, the redundancy is introduced by the FEC code, the number of bits per carrier, namely, the constellation used

in each carrier, and the transmission mode, namely, normal or HURTO mode, are adapted so that the number of bits per information packet along with redundancy approximates, without exceeding, a whole multiple of the number of bits that are transmitted in the OFDM symbol.

**12. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 11, characterized in that in adapting transmission capacity, the following occurs:

- hysteresis margins to both increment and decrease the number of bits per carrier from the comparison of the S/N with the previously fixed S/N thresholds needed to maintain a determined BER, are introduced and all of this so as to avoid the effects of oscillation when S/N reaches a threshold;
- changes modulation only when the number of carriers that must change their modulation is greater than a previously established determined value;
- sends the decisions taken regarding the change of modulation in the carriers via the opposite channel to that used for the estimation and preferably using a control channel or control messages;
- awaits confirmation that the indication of having changed the modulation in the carriers has been received before using this new modulation.

**13. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 10, characterized in that transmission in HURTO mode is selected when estimated S/N is below a previously established value, where this value

indicates that not even a modulation with low S/N requirements along with FEC codes that introduce great redundancy can be used with the guarantee of obtaining a determined BER on exiting the FEC, or when wanting to send information to one or more user equipments with a high probability that they receive this information correctly, such as in the case of control messages, then this transmission mode is preferable.

**14. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 13, characterized in that transmission of information in HURTO mode comprises sending all carriers used with a modulation that has low S/N demodulation needs, preferably QPSK modulation, as well as using forward error correction FEC codes that introduce redundancy sufficient to correct and or detect in reception a large number of errors produced by transmission over the electricity network.

**15. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 14, characterized in that in HURTO mode, the number of times the information is repeated, namely, level of diversity used, is modified from the estimated characteristics of the electricity network, and this modification is done packet by packet; where the equipment receives the same information the same number of times as diversity has been selected in HURTO mode, and carries out a process of combining the various received signals to estimate the information really sent.

**16. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 15, characterized in that the process of combining the various signals received so as to

estimate the information really sent in HURTO mode comprises selectively carrying out the coherent sum of the received signals in diversity and multiplying these by a coefficient based on the S/N of the carriers from which the information was received before demodulation, maximum rate combiner, or independently demodulate the information that comes in diversity and carry out a weighted voting according to the demodulation error signal.

**17. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 16, characterized in that only in the case where diversity in frequency is used before carrying out the combination process or voting, groups of carriers may be selected depending on estimated S/N distribution, or all of these may be used to optimise the method of estimating the information received in diversity.

**18. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 10, characterized in that redundancy introduced by the FEC is dynamically modified to maintain an error rate without altering modulation, number of bits assigned to each of the carriers, and FEC codes with a greater capacity for error correction are used when more noise affects the transmission, preferably in the case where multiple impulsive noises exist.

**19. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 18, characterized in that constellations denser than those acceptable are used in transmission and to maintain a determined BER with a determined S/N, the FEC is adapted so as to introduce greater redundancy to achieve said BER and increase transmission capacity.

**20. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 19, characterized in that FEC adaptation is carried out packet by packet to offer different qualities of service (QoS); indicating to the other extreme the current configuration of the FEC by means of headers used in the packets where this adaptation of the FEC consists of altering the redundancy generated by the FEC on the signal or altering the FEC code used to make it adequate to noise on the line, or altering both aspects.

**21. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK,** according to Claim 1, characterized in that various combinations of bits per carrier, redundancy, FEC codes, transmission mode, and diversity are selected and stored in the user and head-end equipments in a series of tables referring to the various combinations selected; where the purpose of that selection is to offer various qualities of service (QoS); and where change from one combination to another is communicated packet to packet and where the combination of parameters selected is indicated by means of a reference, preferably to a position in the table, that is sent in the message headers.

**22. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 10, characterized in that when the head-end wants to send the same information to a group of user equipments or to all the users in the system, it uses, selectively:

- transmission in HURTO mode;
- constellations modulated with the maximum number of bits per carrier that can be used, provided that all the user equipments in the

group will be capable of demodulating this maximum number of bits per carrier maintaining a determined BER;

- dense constellation, but adding sufficient redundancy in the FEC codes so that all the users in the group will be capable of recuperating the information sent.

**23. PROCESS TO OPTIMISE COMMUNICATION FOR A MULTI-USER OFDM DIGITAL TRANSMISSION SYSTEM OVER THE ELECTRICITY NETWORK**, according to Claim 22, characterized in that the user equipments in the group with the least number of bits per carrier limit the constellation density that can be used in transmission in this carrier for all the users in the group unless redundancy included in the signal is increased, where the values for bits per carrier are known by the head-end equipment and the head-end indicates the number of bits per carrier used in each carrier by means of message headers that are sent to the group of user equipments, and where it also informs on which users belong to the group, namely, dynamic re-assignation of user groups.